Chapter 5
Connections and Details

5-1. General

Connections consist of connecting elements (e.g., stiffeners, gusset plates, angles, brackets) and connectors (bolts, welds, or for older HSS, rivets). Connection design shall conform to the specifications contained in AISC (1986, 1989) and AWS (1990) except as specified herein. Critical connections should be fully detailed by the design engineer. Connections which are considered noncritical may be detailed by the fabricator; however, the designer shall clearly define the requirements of the noncritical connection. Any deviation from details originally specified by the design engineer shall be reviewed and approved by the design engineer. Details that will result in safe economical fabrication methods shall be used. Special critical connections for specific structure types are discussed in the appropriate appendixes.

5-2. Design Considerations

Connections shall be designed to transfer the required forces obtained from the structural analysis, and shall maintain sufficient ductility and rotation capacity to satisfy the particular design assumption. Connection designs must consider stress concentrations, eccentricities, field splices, imposed restraints (fixity), and fatigue resistance. Following is a discussion of these design considerations.

a. Stress concentrations. Avoid abrupt transitions in thickness or width, sharp corners, notches, and other stress raising conditions.

b. Eccentricities. Effects of eccentricity of fastener groups and intersecting members shall be accounted for in the design of connections (see Chapter J of AISC (1986, 1989)).

c. Splices. Shipping restrictions require large HSS to be delivered in sections, which makes field splicing necessary to form the completed structure. Splices should be located in uncongested areas of low or moderate stress. When splices are necessary, they should be shown on the drawings with accompanying splice details or design forces.

d. Restraints. Connections between intersecting members are usually designed to be rigid (original angle between connected members remains fixed) or simple (pinned). If the design assumed a pinned connection, the as-built connection should provide for members to rotate relative to each other to accommodate simple beam end rotation (to accomplish this, inelastic deformation is permitted).

e. Fatigue. Connections shall be designed to minimize the possibility of fatigue damage by using proper detailing practices (see AISC (1984, 1986, 1989) and AASHTO (1978)), and limiting the stress range in accordance with Appendix K of AISC (1986, 1989). Corrosion-fatigue shall be controlled with a well designed and maintained corrosion protection system.

5-3. Bolted Connections

Fully tensioned high-strength bolts shall be used for all HSS structural applications. For nonstructural applications, use of A307 bolts or snug-tight high-strength bolts is allowed, provided requirements of AISC (1986, 1989) are followed. Bolts shall be proportioned for the sum of the external load and tension resulting from prying action produced by deformation of the connected parts. AISC (1984, 1986, 1989) and Kulak, Fisher, and Struik (1987) are useful aids to designing bolted connections.

5-4. Welded Connections

Most HSS are constructed using welded connections. AISC (1984, 1986, 1989) and AWS (1990) are useful aids to selecting the connection details. Welding requirements of AISC (1986, 1989) and AWS (1990) shall be followed. Thick plate weldments shall be designed considering heat requirements (see Section 4 of AWS (1990)), toughness requirements, and geometric requirements (see Section A3 of AISC (1986, 1989) for toughness and geometric requirements). Intersecting and overlapping welds should be avoided. Intermittent welds should be avoided for dynamically loaded members and members subject to corrosion. Through-thickness welds should have backing bars removed and should be ground smooth. The designer shall review and approve the contractor's proposed welding processes and shop drawings.

5-5. Commentary on Paragraph 5-1, General

Connections for HSS are usually in a more severe environment than connections for buildings. HSS connections may be exposed to weather, fresh or salt water, flowing water, and, for many HSS, impacts. AISC (1986 or 1989) can be used as guidance but should be supplemented with AASHTO (1989) since many HSS members have more in common with bridges (sizes, types of connections, and loads) than with steel building frames. Connection details must be consistent with the assumptions used in the design analysis of the structure and must be capable of transferring the required forces between connected members. The forces may consist of any combination of axial or shear loads and bending or torsional moments. Connections may also provide stiffness to limit relative movement between members. Most HSS use welded or bolted connections; however, many older structures have riveted connections.

5-6. Commentary on Paragraph 5-2, Design Considerations

a. Stress concentrations. Stress concentrations in connections are often ignored in design with no decrease in load-carrying capacity. This is because ductility of the steel redistributes localized high stresses. However, this does not mean details that cause stress concentrations can be ignored. Attention should be given to areas of large change in cross section such as termination of cover plates, welds where backing bars have not been removed, and at sharp discontinuities. These details are critical for fatigue resistance. AWS (1990) shows geometries for welded connections that minimize stress concentrations at transitions between members of different thicknesses or widths.

b. Eccentricities.

(1) Axial loads eccentric from fastener group centroids can significantly increase local stresses or individual fastener loads due to additional shear and bending imposed by the eccentricity. While eccentricities in statically loaded single-angle, double-angle, and similar members may be of minor consequence, connections for members subject to cyclic loading should be balanced about their gravity axes; if not, provision shall be made for bending and shearing stresses due to the eccentricity.

(2) The designer has the option of selecting a concentric connection or, in some cases, an eccentric connection. A concentric connection is detailed so that the gravity axes of all members framing into the connection pass through a common point. This ensures that the axial force in an intersecting member does not produce an additional moment in the connection. However, in some cases a concentric connection may be undesirable because it can require poorly shaped elements such as long gusset plates with a limited buckling capacity that is difficult to assess.

(3) An eccentric connection may be detailed to simplify the design of gusset plates. For example, a member may be located such that its line of force passes through the corner of the gusset plate. However, the lines of action of the force in the intersecting members usually do not pass through the same point. The axial force acting eccentrically will produce a moment in the connection which must be distributed among the connected members based on their relative stiffness. See AISC (1984) for illustrated examples.

5-7. Commentary on Paragraph 5-3, Bolted Connections

In the past many HSS have used riveted connections; however, the use of rivets has largely been replaced by use of high strength bolts. Per AISC (1986, 1989), full tightening is required for cyclic loads, for bolts in oversize holes, and when it is necessary to improve water tightness, or if corrosion of the joint is a concern. Therefore, for all HSS structural applications, fully tensioned high-strength bolts shall be used. Bolted connections are much less common on HSS than on buildings or bridges. Typically, bolted connections for HSS are limited to machinery and appurtenances, splices, sill plates, thick plates or jumbo sections (over 1.5 in. thick), steel members embedded in or supported by concrete, locations where future adjustments may be required, or elements that may need replacing sometime during the life of the structure.

5-8. Commentary on Paragraph 5-4, Welded Connections

Many HSS contain thick (greater than 1.5 in. thick) plate weldments. Critical connections on HSS often consist of full penetration or large fillet welds to develop the full strength of a part. Heavy welding is labor intensive and may result in member distortion and large residual stresses. Thick plates and jumbo rolled shapes often exhibit low toughness away from rolled surfaces, and lamellar discontinuities are more prevalent than in thinner plates. Thermal effects due to welding further decrease material toughness and produce high residual stresses which act on these low toughness areas and lamellar discontinuities creating high potential for cracking. The adverse thermal effects are reduced with gradual heating and cooling of the weldment as it is welded, and proper selection of weld process and procedures. Residual stresses in weldments are increased with increasing external constraint so the designer should detail connections to minimize constraint.